Express Mail Label No.

# UTILITY PATENT APPLICATION TRANSMITTAL
## (Large Entity)

*(Only for new nonprovisional applications under 37 CFR 1.53(b))*

| Docket No. |
| --- |
| YO999-523 |
| Total Pages in this Submission |



**TO THE ASSISTANT COMMISSIONER FOR PATENTS**
**Box Patent Application**
**Washington, D.C. 20231**

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

**METHOD AND SYSTEM FOR DIGITAL PRINTING BY DENSITY SCHEDULING**



and invented by:

**Charles Philippe Tresser**

**If a CONTINUATION APPLICATION,** *check appropriate box and supply the requisite information:*

☐ **Continuation** ☐ **Divisional** ☐ **Continuation-in-part (CIP)** of prior application No.: ____________

Which is a:

☐ **Continuation** ☐ **Divisional** ☐ **Continuation-in-part (CIP)** of prior application No.: ____________

Which is a:

☐ **Continuation** ☐ **Divisional** ☐ **Continuation-in-part (CIP)** of prior application No.: ____________

Enclosed are:

**Application Elements**

1. ☒ Filing fee as calculated and transmitted as described below
2. ☒ Specification having 24 pages and including the following:
   - a. ☒ Descriptive Title of the Invention
   - b. ☐ Cross References to Related Applications *(if applicable)*
   - c. ☐ Statement Regarding Federally-sponsored Research/Development *(if applicable)*
   - d. ☐ Reference to Microfiche Appendix *(if applicable)*
   - e. ☒ Background of the Invention
   - f. ☒ Brief Summary of the Invention
   - g. ☒ Brief Description of the Drawings *(if drawings filed)*
   - h. ☒ Detailed Description
   - i. ☒ Claim(s) as Classified Below
   - j. ☒ Abstract of the Disclosure

| UTILITY PATENT APPLICATION TRANSMITTAL (Large Entity) (Only for new nonprovisional applications under 37 CFR 1.53(b)) | Docket No. **YO999-523** |
|---|---|
| | Total Pages in this Submission |

**Application Elements (Continued)**

3. ☒ Drawing(s) *(when necessary as prescribed by 35 USC 113)*
   a. ☐ Formal Number of Sheets ________
   b. ☒ Informal Number of Sheets **5 (Figs. 1-5)**
4. ☒ Oath or Declaration
   a. ☒ Newly executed *(original or copy)* ☐ Unexecuted
   b. ☐ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional application only)*
   c. ☒ With Power of Attorney ☐ Without Power of Attorney
   d. ☐ *DELETION OF INVENTOR(S)*
   Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference *(usable if Box 4b is checked)*
   The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Computer Program in Microfiche *(Appendix)*
7. ☐ Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all must be included)*
   a. ☐ Paper Copy
   b. ☐ Computer Readable Copy *(identical to computer copy)*
   c. ☐ Statement Verifying Identical Paper and Computer Readable Copy

**Accompanying Application Parts**

8. ☒ Assignment Papers *(cover sheet & document(s))*
9. ☐ 37 CFR 3.73(B) Statement *(when there is an assignee)*
10. ☐ English Translation Document *(if applicable)*
11. ☒ Information Disclosure Statement/PTO-1449 ☒ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Acknowledgment postcard
14. ☐ Certificate of Mailing
    ☐ First Class ☐ Express Mail *(Specify Label No.)*: ________

| UTILITY PATENT APPLICATION TRANSMITTAL (Large Entity) *(Only for new nonprovisional applications under 37 CFR 1.53(b))* | Docket No. **YO999-523** |
|---|---|
| | Total Pages in this Submission |

### Accompanying Application Parts (Continued)

15. ☐ Certified Copy of Priority Document(s) *(if foreign priority is claimed)*

16. ☐ Additional Enclosures *(please identify below):*

### Fee Calculation and Transmittal

| CLAIMS AS FILED | | | | | |
|---|---|---|---|---|---|
| **For** | **#Filed** | **#Allowed** | **#Extra** | **Rate** | **Fee** |
| **Total Claims** | 46 | - 20 = | 26 | x $18.00 | $468.00 |
| **Indep. Claims** | 6 | - 3 = | 3 | x $78.00 | $234.00 |
| **Multiple Dependent Claims (check if applicable)** ☐ | | | | | $0.00 |
| | | | | **BASIC FEE** | $690.00 |
| **OTHER FEE** ***(specify purpose)*** | **Assignment Recordation** | | | | $40.00 |
| | | | | **TOTAL FILING FEE** | $1,432.00 |

☒ A check in the amount of **$1,432.00** to cover the filing fee is enclosed.

☒ The Commissioner is hereby authorized to charge and credit Deposit Account No. **50-0481** as described below. A duplicate copy of this sheet is enclosed.

- ☐ Charge the amount of as filing fee.
- ☒ Credit any overpayment.
- ☒ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.
- ☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.311(b).

*Signature*

Dated: **May 26, 2000**

**Sean M. McGinn, Esq.**
**Reg. No.: 34,386**

cc:

**Customer No.: 21254**

MCGINN & GIBB, P.C.
A PROFESSIONAL LIMITED LIABILITY COMPANY
PATENTS, TRADEMARKS, COPYRIGHTS, AND INTELLECTUAL PROPERTY LAW
1701 CLARENDON BOULEVARD, SUITE 100
ARLINGTON, VIRGINIA 22209
TELEPHONE (703) 294-6699
FACSIMILE (703) 294-6696

# APPLICATION FOR UNITED STATES LETTERS PATENT

| | |
|---|---|
| APPLICANT: | Charles Philippe Tresser |
| FOR: | METHOD AND SYSTEM FOR DIGITAL PRINTING BY DENSITY SCHEDULING |
| DOCKET NO.: | YO999-523 |

# METHOD AND SYSTEM FOR DIGITAL PRINTING BY DENSITY SCHEDULING

## BACKGROUND OF THE INVENTION

### *Field of the Invention*

The present invention generally relates to method and system for digital printing, and more particularly to a method and system for digital printing, mostly addressed at printing images, which exploit better the two-dimensional aspect of images than error diffusion methods, and take much more account of the image than dithering methods.

### *Description of the Related Art*

Most printers today can print in only a limited number of colors. Digital half-toning is a technique for printing a picture (or more generally displaying it on some two-dimensional medium) using small dots with a limited number of colors such that it appears to consist of many colors when viewed from a proper distance. For example, a picture of black and white dots can appear to display gray colors when viewed from some distance.

The fastest and most commonly used methods for digital half-toning are dithering

algorithms which use threshold arrays (i.e., also called dither matrices or dither masks).

The principle of this conventional method, as illustrated by Figure 1, is well known. The method allows to associate a matrix N of discrete values at 13 (typically "0" or "1", where "1" means a pixel is printed, and a "0" means nothing is printed) to an image I at 11 using a dithering mask 12 (i.e., a usually smaller matrix of threshold values). Various masks can be devised, according to the needs of precise applications, and several methods to devise masks with good performance have been disclosed (e.g., see U.S. Patent No. 5,111,310 to Parker et al., U.S. Patent No. 5,917,951 to Thompson et al., and U.S. Patent No. 6,025,930 to Thompson et al., each incorporated herein by reference).

However, instead of a dithering mask, one can also use other half-toning algorithms such as an error diffusion algorithm.

Before defining this class of techniques, it is noted that when using dithering, one could treat each pixel at any stage of the process, or treat a lot of the pixels in parallel, as the printing decision at each pixel (i.e., to print or not to print at that place) does not depend of the decision at any other point. In practice, one treats the pixels one-by-one, line-by-line, but this is just a matter of practicality, not a need of the method.

To the contrary, error diffusion is rasterization-dependent. That is, one can choose an order in which the pixels will be dealt with, e.g., line-by-line going down the page, and from left to right on each line. Once this order is chosen, before making a printing decision at pixel (i, j) (i.e., choosing which color(s) will be printed at that pixel, if any), one modifies the input at (i, j) by weighted errors made previously in the neighborhood, and computes a new error as the difference between the modified input and the printing decision.

Dithering masks as well as error diffusion can be easily adapted to use more than two possible outputs per pixel (i.e., several levels of gray instead of just black and white). In such a case, one then speaks of multi-tone printers (with a digital printer then referring to black and white pixels only). Also, all these techniques, can be easily adapted to color printing. That is, both adaptation to multi-tone and to color (i.e., digital or multi-tone color) are well known by one versed in the art of digital printing.

A well-known difficulty associated with dithering for a color image is linked to the fact that shifts on the paper, or the printing guns, may occur between different color components, which is known to create undesirable moiré patterns. This problem is usually corrected by using different masks in the various color planes.

Most of these techniques are reviewed in the book *Digital Halftoning*, MIT Press, Cambridge, MA (1987) by R. Ulichney, which is a general reference for digital half-toning in black and white. Regarding color, "Optical Color technology for electronic imaging devices" by Kang, Henry R. (Bellingham, Wash., USA: SPIE Optical, 1997) is a general reference for color digital printing.

Other, more global, and very much more time-consuming, methods have been proposed to perform digital half-toning, such as the use of neural networks or global optimization.

Thus, it is easy to understand why dithering works well for a uniform grey input. To the contrary, one can easily exhibit examples of images whose rendering by digital printing would be arbitrarily bad if using a dithering mask. This is because dithering only considers one pixel at a time. The reasonable results one obtains in practice for a natural image, such as pictures of natural scenes, are linked to the fact that, in general, such pictures are quite smooth. For

purposes of the present invention, "smooth" refers to a generally slow variation of the output from a pixel to the neighboring ones. Some poor cases are nevertheless commonly encountered.

Error diffusion avoids this problem to some extent, but suffers from the fact that it is attached to an arbitrary raster choice which by nature, destroys the fundamental 2-dimensional nature of images. More sophisticated methods which aim at global optimization in some sense are very slow.

## SUMMARY OF THE INVENTION

In view of the foregoing and other problems, disadvantages, and drawbacks of the conventional methods and structures, an object of the present invention is to provide a method and system which is much faster than the search of global optimum, but which still can deal with the 2-dimensional aspect of the images.

In a first aspect, a method (and system) of digital printing includes forming a sequence of matrices $P_k$ with entries 0 or 1 where a 1 at some entry in some $P_k$ represents that this pixel will be printed at stage k, constructing as sequences of matrices $I_k$ with entries in [0, 1], so that $I_0 = I$, determining, when considering all pixels, a next pixel having a largest weight indicating that the next pixel is to be printed first, printing the pixel, and determining for each pixel of the remaining ones of pixels of the plurality of pixels a printing order of the remaining pixels such that subsequent pixels of the remaining ones of pixels of the plurality of pixels having a largest weight among the remaining pixels, are subsequently printed.

In a second áspect, a method (and system) of printing includes forming a matrix of pixels, determining an order of printing of the pixels, the determining including finding a weight of the pixels and printing a pixel having a highest weight, and reordering the remaining pixels and printing a pixel having the greatest weight of the remaining pixels until all pixels have been printed.

Further, a program storage medium is provided for storing program steps of the inventive methods.

With the unique and unobvious features of the present invention, a method and system are provided which are much faster than the search of global optimum, but which still can deal with the 2-dimensional aspect of the images without treating each pixel independently of its neighbors.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, aspects and advantages will be better understood from the following detailed description of a preferred embodiment of the invention with reference to the drawings, in which:

Figure 1 illustrates the use of dither masks for half-toning, according to conventional methods;

Figure 2 shows a flow diagram which represents an exemplary method 200 of implementing the present invention;

Figure 3 shows the structure of weights in a neighborhood V(i, j) for a preferred embodiment of the present invention;

Figure 4 illustrates an exemplary hardware/information handling system 400 for incorporating the present invention therein; and

FIG. 5 illustrates a signal bearing medium 500 (i.e., storage medium) for storing steps of a program of a method according to the present invention.

## DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT OF THE PRESENT INVENTION

Turning to Figures 2-5, a detailed description of a preferred embodiment according to the present invention will be described.

Prior to describing the preferred embodiment of the present invention and to make the description more precise, some notations will be introduced. Below, considered in detail is the case of digital printing with black and white dots of greyscale images. Other cases such as multi-tone and color will be discussed later.

The original image will be denoted as the matrix $I=\{I(i, j)\}$, where $1 \leq i \leq Himage$ and $1 \leq j \leq Vimage$. Each element I(i, j) of I is a real number between 0 and 1, where 0 means "white" and 1 means "black".

The set of pixels to be printed after half-toning will be encoded in the matrix $P = \{P(i, j)\}$, where $1 \leq i \leq Himage$ and $1 \leq j \leq Vimage$ (i.e., this notation represents "horizontal" and

"vertical" coordinates of the image). Each element P(i, j) of P is either 0 or 1, where again "0" means "white" and "1" means "black". It will be convenient to understand P as obtained from the constant 0 matrix by replacing as many 0s by 1s as needed to represent I.

Given an Himage-by-Vimage matrix M with entries in [0, 1], some neighborhood V(i, j, M) is chosen for each (i, j), whose shape and size may either depend or not depend on (i, j), and a set of weights associated to all pixels in V(i, j, M). Then, W(i, j, M) stands for the weighted average of the elements of M in V(i, j, M).

Then, set GreyTotal= $\Sigma_{i,j}I(i,j)$.

Hereinbelow and referring to Figure 2, a method (algorithm) 200 is described which constructs a sequence of matrices $P_k$ with entries 0 or 1, the last one being the matrix P preferably sought by the present invention. In the process, there will be constructed sequences of matrices $I_k$ with entries in [0,1], so that $I_0 = I$.

INITIALIZATION:

At step 201, first initialization is performed. That is, set k = 0 and define $P_0$ as the constant Himage-by-Vimage zero matrix.

LOOP:

In step 202, replace k by k+1 (i.e., as usual in languages such as FORTRAN, k now stands for what would have been k+1 before Step 1) and so forth for each iteration, and in step 203 set $I_k = I_{k-1}$, $P_k = P_{k-1}$.

In step 204, determine whether there has been a change in $V(i, j, M_k)$. In steps 205 and 206, compute all $W(i, j, I_k)$ (weighted average) not computed so far and set $W(i, j, I_k) = W(i, j, I_{k-1})$ if $W(i, j, I_k)$ is not computed again (i.e., when $k = 1$, one computes them all, and for $k>1$, one computes those which have been modified at the previous iteration).

In step 207, order all $W(i, j, I_k)$ by decreasing order, and in step 208 call Max(k) the bigger value of all $W(i, j, I_k)$s.

In step 209, it is determined whether $W(i, j, I_k) = \mathrm{Max}(k)$.

For all pairs (i, j) such that $W(i, j, I_k) = \mathrm{Max}(k)$ (i.e., a YES" in step 209), then in step 210, replace $P_k(i, j) = 0$ with $P_k(i, j) = 1$ in $P_k$, and $I_k(i, j) = I(i, j)$ with $I_k(i, j) = I(i, j)-1$ in $I_k$. If a "NO" results in step 209, then the process loops to step 211 in which nothing at (i, j) is changed.

The process continues to step 212. In step 212, compute $\mathrm{GreyTotal}(k) = \sum_{i,j} P_k(i, j)$.

Then, if GreyTotal(k) < GreyTotal as determined in step 213, then the process loops to go to step 202 for the next iteration.

Conversely, if GreyTotal ≤ GreyTotal(k) as determined in step 214, and $|\mathrm{GreyTotal}-\mathrm{GreyTotal}(k)| < |\mathrm{GreyTotal}-\mathrm{GreyTotal}(k-1)|$ as determined in step 215, then in step 216 set $P = P_k$.

Alternatively, if GreyTotal ≤ GreyTotal(k) as determined in step 214, and $|\mathrm{GreyTotal}-\mathrm{GreyTotal}(k)| \geq |\mathrm{GreyTotal}-\mathrm{GreyTotal}(k-1)|$ as determined in step 215, then in step 217, set $P = P_{k-1}$. Thereafter, the process ends.

Of course, as would be known by one of ordinary skill in the art taking the present application as a whole, step 202 can easily be modified to vary the total number of black dots being printed, for instance to take account of the actual size of printed dots, compensate for originals which are too clear or too dark, just for a matter of taste, etc.

To apply this method with a multi-tone printer, one prints the lightest grey darker than Max(k) (instead of necessarily a black dot in one bit per pixel printers), and replaces

$$I_k(i, j) = I(i, j) - 1$$

by

$$I_k(i, j) = I(i, j) - \text{``multibit grey level being printed''}$$

in steps 209-211 above.

To apply this method to color images, the image I is decomposed as usual in the color planes accessible to the printer ( i.e., Cyan, Magenta, and Yellow, or Cyan, Magenta, Yellow, and Black) and then the method is used, as described above, in each plane. Then, in each color plane, either one bit or multi-tone printing can be accommodated readily.

The invention can further be adapted to accommodate for the fact that some printers (e.g., such as some laser printers) require dark pixels to be grouped together, forming so-called half-tone dots, to compensate for isolated pixels that do not print in a predictable and trustable way.

This accommodation is achieved by making the weights in V(i, j, M) depend also on what is printed at (i, j), for instance to favor printing near a pixel already designed to be printed. For instance, near a pixel already designed to be printed, the sum of the weights in V(i, j) may be greater than one, and otherwise may be smaller than one.

Thus; with the unique and unobvious features of the present invention, the tradeoff between performance and time required is optimized in that the time required by the inventive method, which may be greater than that for the conventional dither etc. techniques, is much smaller than for global optimization and other global methods. Conversely, the performance is much better than for the conventional dither etc. techniques.

Figure 4 illustrates a typical hardware configuration of an information handling/computer system in accordance with the invention and which preferably has at least one processor or central processing unit (CPU) 411.

The CPUs 411 are interconnected via a system bus 412 to a random access memory (RAM) 414, read-only memory (ROM) 416, input/output (I/O) adapter 418 (for connecting peripheral devices such as disk units 421 and tape drives 440 to the bus 412), user interface adapter 422 (for connecting a keyboard 424, mouse 426, speaker 428, microphone 432, and/or other user interface device to the bus 412), a communication adapter 434 for connecting an information handling system to a data processing network, the Internet, an Intranet, a personal area network (PAN), etc., and a display adapter 436 for connecting the bus 412 to a display device 438 and/or printer 439. As mentioned above, the printer 439 may be a digital printer or the like.

In addition to the hardware/software environment described above, a different aspect of the invention includes a computer-implemented method for performing the above method. As an example, this method may be implemented in the particular environment discussed above.

Such a method may be implemented, for example, by operating a computer, as embodied by a digital data processing apparatus, to execute a sequence of machine-readable instructions. These instructions may reside in various types of signal-bearing media.

Thus, this aspect of the present invention is directed to a programmed product, comprising signal-bearing media tangibly embodying a program of machine-readable instructions executable by a digital data processor incorporating the CPU 411 and hardware above, to perform the method of the invention.

This signal-bearing media may include, for example, a RAM contained within the CPU 411, as represented by the fast-access storage for example. Alternatively, the instructions may be contained in another signal-bearing media, such as a magnetic data storage diskette 500 (Figure 6), directly or indirectly accessible by the CPU 411.

Whether contained in the diskette 500, the computer/CPU 411, or elsewhere, the instructions may be stored on a variety of machine-readable data storage media, such as DASD storage (e.g., a conventional "hard drive" or a RAID array), magnetic tape, electronic read-only memory (e.g., ROM, EPROM, or EEPROM), an optical storage device (e.g. CD-ROM, WORM, DVD, digital optical tape, etc.), paper "punch" cards, or other suitable signal-bearing media including transmission media such as digital and analog and communication links and wireless. In an illustrative embodiment of the invention, the machine-readable instructions may comprise software object code, compiled from a language such as "C", etc.

With the unique and unobvious aspects of the present invention, a method and system are provided in which the tradeoff between performance and time required is optimized in that the time required by the inventive method, which is greater than that for the conventional error

diffusion, dithering etc. techniques, is much smaller than for global optimization and other global methods. Conversely, the performance is much better than for the conventional error diffusion, dithering etc. techniques. Indeed, the invention exploits between the two-dimensional aspect of the images than error diffusion methods and takes much more account to the image that dithering methods. Thus, the inventive method and system are much faster than the search of global optimum, but can still cope with the 2-dimensional aspect of the images.

While a preferred embodiment of the present invention has been described above, it should be understood that it has been provided as an example only. Thus, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the appended claims.

**CLAIMS**

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is as follows:

1. A method for digital printing represented as a matrix I, comprising:

forming a sequence of matrices $P_k$ with entries 0 or 1 where a 1 at some entry in some $P_k$ represents that this pixel will be printed at stage k;

constructing as sequences of matrices $I_k$ with entries in [0, 1], so that $I_0 = I$;

determining, when considering all pixels in $I_k$ for all succesive values of k, a next pixel having a largest weight indicating that said next pixel is to be printed next , so that $P_{k+1}$ differs from $P_k$ by a zero at said next pixel in $P_k$ being replaced by a 1 at the same position in $P_{k+1}$;

printing said pixel;

replacing the value of said pixel in $I_k$ by a 0 thus forming $I_{k+1}$; and

incrementing the value of k, until enough pixels have been printed to represent the overall darkness of I by the printed image.

2. The method according to claim 1, wherein with each printing of a pixel, an order of printing of remaining pixels is redefined.

3. The method according to claim 1, further comprising reordering the pixels to be printed with each printing iteration.

4. The method according to claim 1, wherein an original image is denoted as said matrix $I = \{I(i, j)\}$, where $1 \leq i \leq$Himage and $1 \leq j \leq$Vimage, and

wherein each element $I(i, j)$ of $I$ is a real number between 0 and 1 where 0 represents "white", 1 represents "black" and intermediate values represent levels of grey.

5. The method according to claim 4, wherein said matrix forming includes:

setting $k = 0$ and defining $P_0$ as the constant Himage by Vimage zero matrix.

6. The method according to claim 5, further comprising:

with each iteration of redetermining, replacing k by k+1; and

setting $I_k = I_{k-1}$ and $P_k = P_{k-1}$ except for a single pixel.

7. The method according to claim 6, further comprising:

determining whether there has been a change in $V(i, j, M_k)$;

computing all weighted averages $W(i, j, I_k)$ not computed in earlier iterations and setting $W(i, j, I_k) = W(i, j, I_{k-1})$ if $W(i, j, I_k)$ is not computed again, such that when k=1, all said weighted averages are computed, and for k>1, only said weighted averages which have been modified at a previous iteration are computed.

8. The method according to claim 7, further comprising:

ordering all $W(i, j, I_k)$ by decreasing order; and

considering $Max(k)$ as a larger value of all $W(i, j, I_k)$s.

9. The method according to claim 8, further comprising:

determining whether $W(i, j, I_k) = Max(k)$.

10. The method according to claim 9, further comprising:

for all pairs (i, j) such that $W(i, j, I_k) = Max(k)$, replacing $P_k(i, j) = 0$ with $P_k(i, j) = 1$ in $P_k$, and $I_k(i, j) = I(i, j)$ with $I_k(i, j) = I(i, j)-1$ in $I_k$.

11. The method according to claim 9, further comprising:

computing $GreyTotal(k) = \sum_{i,j} P_k(i, j)$.

12. The method according to claim 11, wherein if $GreyTotal(k) < GreyTotal$, then a next iteration is begun.

13. The method according to claim 11, further comprising:

if $GreyTotal \leq GreyTotal(k)$, and $|GreyTotal-GreyTotal(k)| < |GreyTotal-GreyTotal(k-1)|$, then set $P=P_k$.

14. The method according to claim 11, further comprising:

if GreyTotal $\leq$ GreyTotal(k), and |GreyTotal-GreyTotal(k)| $\geq$ |GreyTotal-GreyTotal(k-1)|, then set $P = P_{k-1}$.

15. The method according to claim 1, wherein a total number of black dots being printed is variable.

16. The method according to claim 15, further comprising:

providing a multi-tone printer, such that a lightest grey darker than Max(k) is printed, and $I_k(i, j) = I(i, j) - 1$ is replaced by $I_k(i, j) = I(i, j)$ which represents a multibit grey level being printed.

17. The method according to claim 9, further comprising:

compensating for isolated pixels by making weights in V(i, j, M) depend on what is printed at (i, j).

18. The method according to claim 1, further comprising:

encoding the set of pixels to be printed after half-toning, in the matrix $P=\{P(i, j)\}$, where $1 \leq i \leq$ Himage and $1 \leq j \leq$Vimage, wherein each element P(i,j) of P has a value of either 0 or 1, where "0" represents "white" and "1" represents "black".

19. The method according to claim 18, further comprising:

given a Himage by Vimage matrix M with entries in [0,1], selecting a neighborhood V(i, j, M) for each (i, j), whose shape and size selectively depends or not on (i, j), and a set of weights associated to all pixels in V(i, j, M).

20. The method according to claim 19, wherein W(i, j, M) represents a weighted average of the elements of M in V(i, j, M), and GreyTotal= $\Sigma_{i,j}$ I(i, j).

21. A method of printing, comprising:

forming a matrix of pixels;

determining an order of printing of said pixels, said determining including finding a weight of said pixels and printing a pixel having a highest weight; and

reordering the remaining pixels and printing a pixel having the greatest weight of the remaining pixels until all pixels have been printed.

22. The method according to claim 21, wherein the pixels are printed in turn based on the darkness of the local image being printed.

23. A method for digital printing, comprising:

forming a sequence of matrices $P_k$ with entries 0 or 1 where a 1 at some entry in some $P_k$ represents that this pixel will be printed at stage k;

constructing as sequences of matrices $I_k$ with entries in [0, 1], so that $I_0 = I$;

determining, for a plurality of pixels in $I_k$ for all successive values of k, a next pixel having a largest weight indicating that said first pixel is to be printed next;

printing said pixel; and

determining for each pixel of the remaining ones of pixels of said plurality of pixels a printing order of said remaining pixels such that subsequent pixels of said remaining ones of pixels of said plurality of pixels having a largest weight among the remaining pixels, are subsequently printed.

24. A system for printing, comprising:

means for forming a matrix of pixels;

means for determining an order of printing of said pixels, said determining including finding a weight of said pixels and printing a pixel having a highest weight; and

means for reordering the remaining pixels and printing a pixel having the greatest weight of the remaining pixels until all pixels have been printed.

25. The system according to claim 24, wherein with each printing of a pixel, an order of printing of remaining pixels is redefined.

26. The system according to claim 24, wherein said reordering means reorders the pixels to be printed with each printing iteration.

27. The system according to claim 24, wherein an original image is denoted as said matrix $I = \{I(i, j)\}$, where $1 \leq i \leq Himage$ and $1 \leq j \leq Vimage$, and

wherein each element $I(i, j)$ of I is a real number between 0 and 1 where 0 represents "white", 1 represents "black" and intermediate values represent levels of grey.

28. The system according to claim 27, wherein said matrix forming means includes:

means for setting $k = 0$ and defining $P_0$ as the constant Himage by Vimage zero matrix.

29. The system according to claim 28, further comprising:

with each iteration of redetermining, means for replacing k by k+1; and

means for setting $I_k = I_{k-1}$ and $P_k = P_{k-1}$ except for a single pixel.

30. The system according to claim 29, further comprising:

means for determining whether there has been a change in $V(i, j, M_k)$; and

means for computing all weighted averages $W(i, j, I_k)$ not computed in earlier iterations and setting $W(i, j, I_k) = W(i, j, I_{k-1})$ if $W(i, j, I_k)$ is not computed again, such that when k=1, all said weighted averages are computed, and for k>1, only said weighted averages which have been modified at a previous iteration are computed.

31. The system according to claim 30, further comprising:

means for ordering all $W(i, j, I_k)$ by decreasing order; and

means for considering Max(k) as a larger value of all $W(i, j, I_k)$s.

32. The system according to claim 31, further comprising:

means for determining whether $W(i, j, I_k) = Max(k)$.

33. The system according to claim 32, further comprising:

for all pairs (i, j) such that $W(i, j, I_k) = Max(k)$, means for replacing $P_k(i, j) = 0$ with $P_k(i, j) = 1$ in $P_k$, and $I_k(i, j) = I(i, j)$ with $I_k(i, j) = I(i, j)-1$ in $I_k$.

34. The system according to claim 32, further comprising:

means for computing $GreyTotal(k) = \sum_{i,j} P_k(i, j)$.

35. The system according to claim 34, wherein if GreyTotal(k) < GreyTotal, then a next iteration is begun.

36. The system according to claim 34, further comprising:

if $GreyTotal \leq GreyTotal(k)$, and $|GreyTotal-GreyTotal(k)| < |GreyTotal-GreyTotal(k-1)|$, means for setting $P=P_k$.

37. The system according to claim 34, further comprising:

if GreyTotal $\leq$ GreyTotal(k), and |GreyTotal-GreyTotal(k)| $\geq$ |GreyTotal-GreyTotal(k-1)|, means for setting $P = P_{k-1}$.

38. The system according to claim 24, wherein a total number of black dots being printed is variable.

39. The system according to claim 38, further comprising:

a multi-tone printer for printing, such that a lightest grey darker than Max(k) is printed, and $I_k(i, j) = I(i, j) -1$ is replaced by $I_k(i, j) = I(i, j)$ which represents a multibit grey level being printed.

40. The system according to claim 32, further comprising:

means for compensating for isolated pixels by making the weights in V(i, j, M) depend on what is printed at (i, j).

41. The system according to claim 24, further comprising:

means for encoding the set of pixels to be printed after half-toning, in the matrix P={P(i, j)}, where $1 \leq i \leq$ Himage and $1 \leq j \leq$Vimage, wherein each element P(i,j) of P has a value of either 0 or 1, where "0" represents "white" and "1" represents "black".

42. The system according to claim 41, further comprising:

given a Himage by Vimage matrix M with entries in [0,1], means for selecting a neighborhood V(i, j, M) for each (i, j), whose shape and size selectively depends or not on (i, j), and a set of weights associated to all pixels in V(i, j, M).

43. The system according to claim 42, wherein W(i, j, M) represents a weighted average of the elements of M in V(i, j, M), and GreyTotal= $\Sigma_{i,j}$ I(i, j).

44. The system according to claim 24, wherein the pixels are printed in turn based on the darkness of the local image being printed.

45. A signal-bearing medium tangibly embodying a program of machine-readable instructions executable by a digital processing apparatus to perform a method of printing, said method comprising:

forming a matrix of pixels;

determining an order of printing of said pixels, said determining including finding a weight of said pixels and printing a pixel having a highest weight; and

reordering the remaining pixels and printing a pixel having the greatest weight of the remaining pixels until all pixels have been printed.

46. A signal-bearing medium tangibly embodying a program of machine-readable instructions executable by a digital processing apparatus to perform a method of printing, said method comprising:

forming a sequence of matrices $P_k$ with entries 0 or 1 where a 1 at some entry in some $P_k$ means that this pixel will be printed at stage k;

constructing as sequences of matrices $I_k$ with entries in [0, 1], so that $I_0 = I$;

determining, when considering all pixels in $I_k$ for all successive values of k, a next pixel having a largest weight indicating that said next pixel is to be printed next , so that $P_{k+1}$ differs from $P_k$ by a zero at said next pixel in $P_k$ being replaced by a 1 at the same position in $P_{k+1}$;

printing said pixel;

replacing the value of said pixel in $I_k$ by a 0 thus forming $I_{k+1}$; and

incrementing the value of k, until enough pixels have been printed to represent the overall darkness of I by the printed image.

# METHOD AND SYSTEM FOR DIGITAL PRINTING BY DENSITY SCHEDULING

## ABSTRACT OF THE DISCLOSURE

A method (and system) of printing, includes forming a matrix of pixels, determining an order of printing of the pixels, the determining including finding a weight of the pixels and printing a pixel having a highest weight, and reordering the remaining pixels and printing a pixel having the greatest weight of the remaining pixels until all pixels have been printed.

# Dither masks

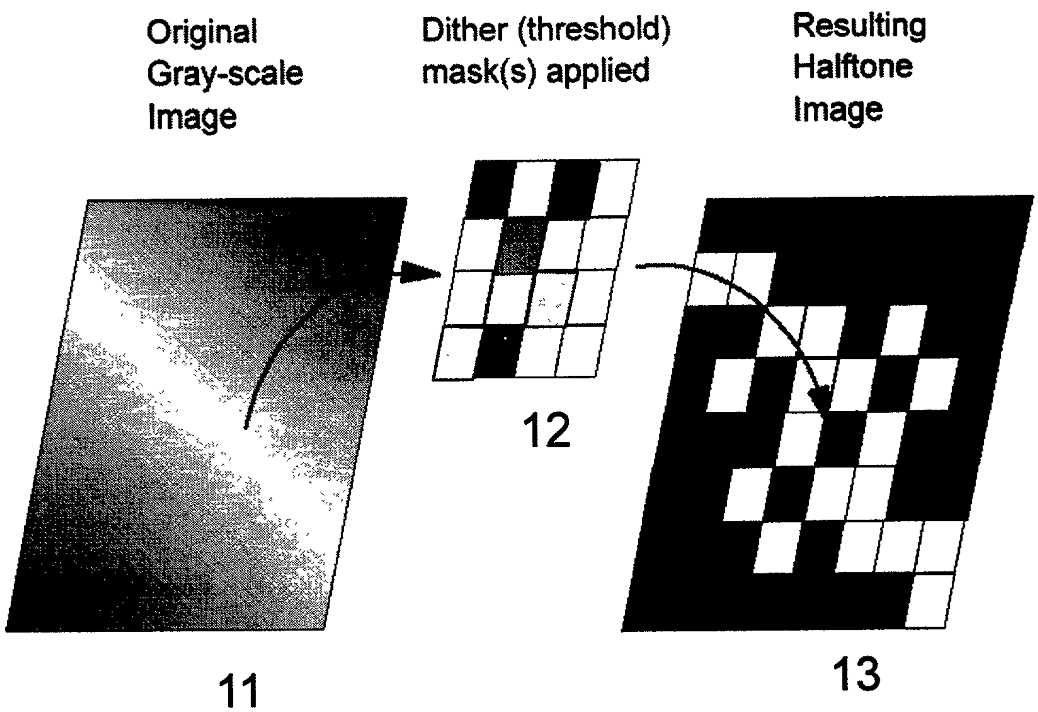
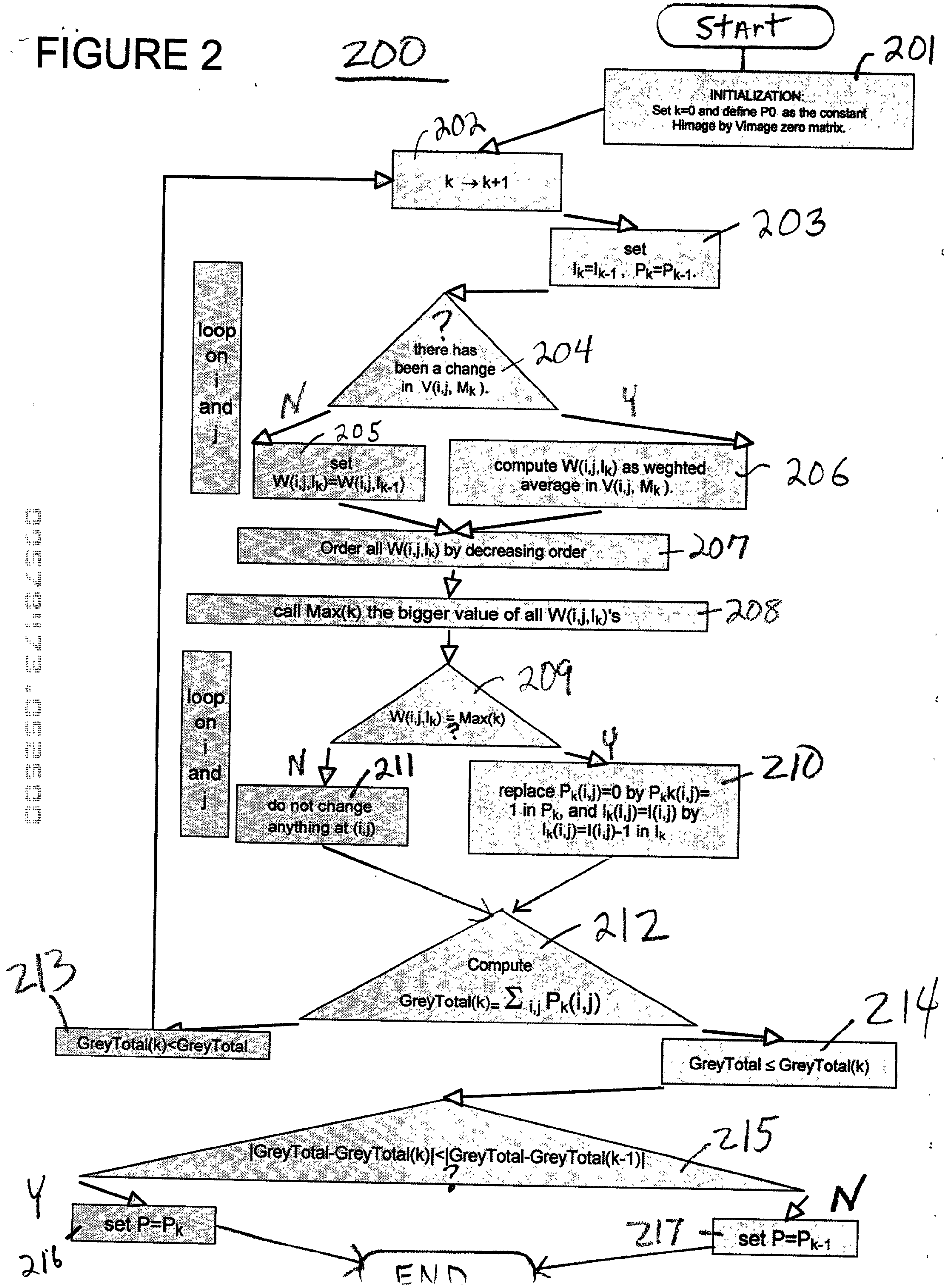


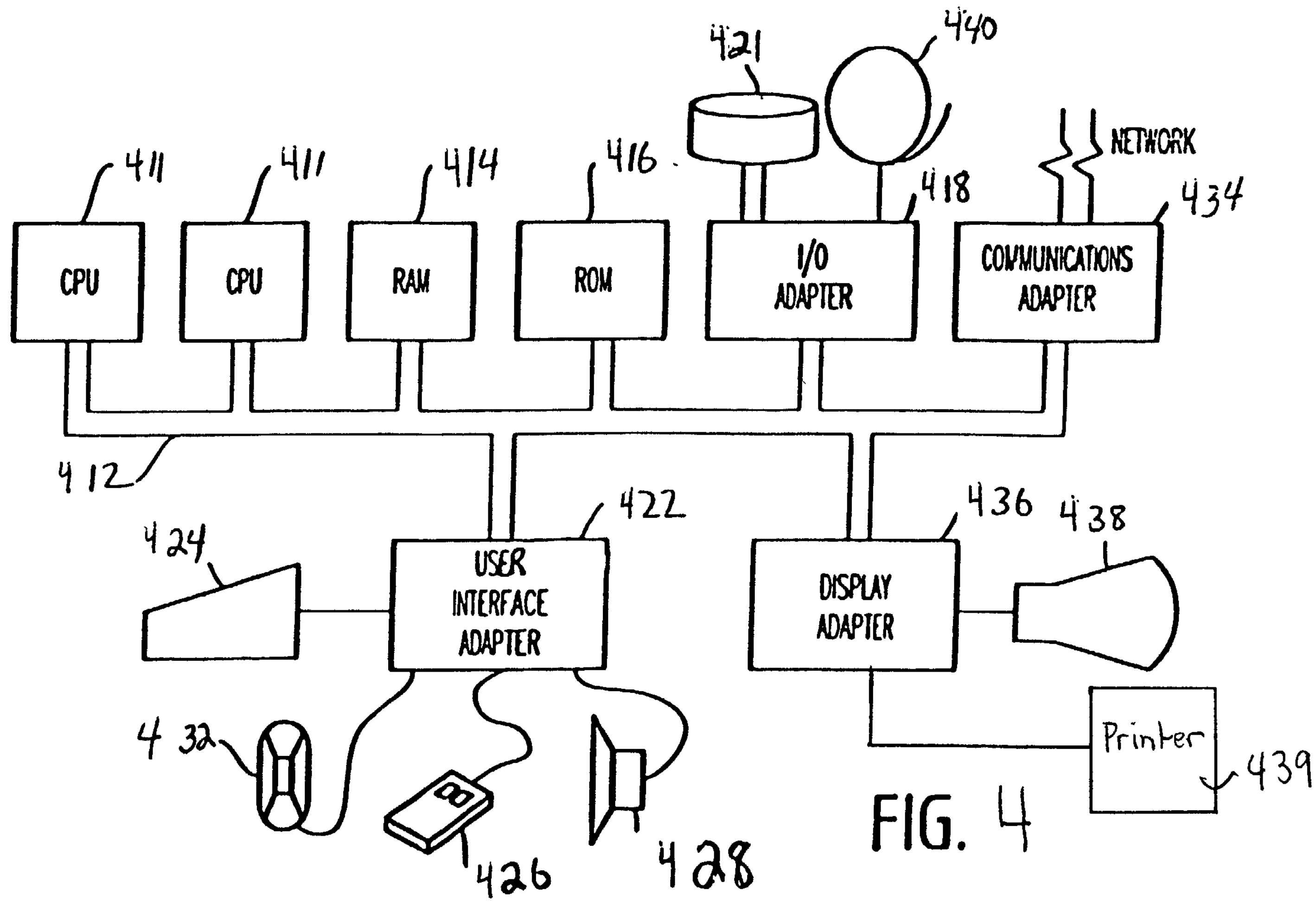

FIGURE 1

FIGURE 2


200
Start
201
INITIALIZATION:
Set k=0 and define P0 as the constant Himage by Vimage zero matrix.
202
k → k+1
203
set
Ik=Ik-1 , Pk=Pk-1.
loop on i and j
?
there has been a change in V(i,j, Mk ).
204
N
Y
205
set
W(i,j,Ik)=W(i,j,Ik-1)
compute W(i,j,Ik) as weghted average in V(i,j, Mk ).
206
Order all W(i,j,Ik) by decreasing order
207
call Max(k) the bigger value of all W(i,j,Ik)'s
208
loop on i and j
W(i,j,Ik) = Max(k) ?
209
N
Y
211
do not change anything at (i,j)
replace Pk(i,j)=0 by Pkk(i,j)= 1 in Pk, and Ik(i,j)=I(i,j) by Ik(i,j)=I(i,j)-1 in Ik
210
Compute
GreyTotal(k)= Σ i,j Pk(i,j)
212
213
GreyTotal(k)<GreyTotal
214
GreyTotal ≤ GreyTotal(k)
|GreyTotal-GreyTotal(k)|<|GreyTotal-GreyTotal(k-1)|
?
215
Y
N
set P=Pk
216
217
set P=Pk-1
END

# FIGURE 3

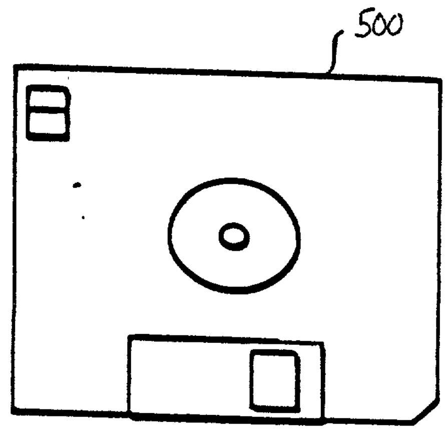
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 4 | 3 | 2 | 1 |
| 2 | 3 | 4 | 5 | 6 | 5 | 4 | 3 | 2 |
| 3 | 4 | 5 | 6 | 8 | 6 | 5 | 4 | 3 |
| 4 | 5 | 6 | 9 | 12 | 9 | 6 | 5 | 4 |
| 5 | 6 | 8 | 12 | 30 | 12 | 8 | 6 | 5 |
| 4 | 5 | 6 | 9 | 12 | 9 | 6 | 5 | 4 |
| 3 | 4 | 5 | 6 | 8 | 6 | 5 | 4 | 3 |
| 2 | 3 | 4 | 5 | 6 | 5 | 4 | 3 | 2 |
| 1 | 2 | 3 | 4 | 5 | 4 | 3 | 2 | 1 |



411
CPU
411
CPU
414
RAM
416
ROM
421
440
418
I/O ADAPTER
NETWORK
434
COMMUNICATIONS ADAPTER
412
424
422
USER INTERFACE ADAPTER
436
438
DISPLAY ADAPTER
Printer
439
432
426
428


FIG. 4

FIG. 5



IBM Docket No.: YO999-523

# DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: METHOD AND SYSTEM FOR DIGITAL PRINTING BY DENSITY SCHEDULING

the specification of which:
(check one)

☒ is attached hereto.
☐ was filed on __________, as Application Serial No. ______________ and was amended on __________.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):

| Number | Country | Day/Month/Year | Priority Claimed |
|---|---|---|---|

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Prior U.S. Applications:

| Serial No. | Filing Date | Status |
|---|---|---|

I hereby declare that all statements made herein of my own knowledge are true arid that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

As a named inventor, I hereby appoint the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: We hereby appoint Manny Schecter, Registration No.31,722, Terry J. Ilardi, Registration No. 29,936, Christopher A. Hughes, Registration No. 26,914, Edward A. Pennington, Registration No. 32,588, John E. Hoel, Registration No. 26,279, Joseph C. Redmond, Jr., Registration No. 18,753, Douglas W. Cameron, Registration No. 31,596, Louis P. Herzberg, Registration No. 41,500, Kevin M. Jordan, Registration No.40,277, Stephen C. Kaufman, Registration No.29,551, Daniel P. Morris, Registration No.32,053, Louis J. Percello, Registration No.33,206, Jay P. Sbrollini, Registration No. 36,266, David M. Shofi, Registration No. 39,835, Paul J. Otterstedt, Registration No. 37,411 and Robert M. Trepp, Registration No. 25,933, to prosecute this application and transact all business in the United States Patent and Trademark Office connected therewith.

Send all correspondence to: **McGinn & Gibb, P.C., 1701 Clarendon Boulevard, Suite 100, Arlington, Virginia 22209. Customer No. 21254**

Telephone calls should be directed to Sean M. McGinn, McGinn & Gibb, P.C. at (703) 294-6699.

(1) Inventor: Charles Philippe Tresser

Signature: ______________________ Date: 5/25/2000

Residence: 953 West Boston Post Road, Mamaroneck, New York 10543

Citizenship: France

Post Office Address: Same as Residence